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CHEESE PESTS AND THEIR CONTROL

BY

E. R. DEONG AND C. L. ROADHOUSE

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THE ECONOMIC IMPORTANCE OF CHEESE PESTS

Correspondence with cheese dealers and experts in California, Indiana, Massachusetts, New York, Oregon, Pennsylvania, and Wisconsin has indicated the presence of cheese mites and skippers in these states. Other sections of the United States are also affected, but the states mentioned manufacture the greater part of the cheese made in this country. Infestation of cheese-curing rooms in California has not been frequent, but when occurring, has been persistent.

The cheese manufactured in California in 1920 was valued at \$4,060,104,⁴ while the total cheese output for the same year in the United States was valued at \$122,403,216.¹⁰ It is difficult to estimate the exact damage due to cheese pests. The losses include the actual injury due to the presence of cheese skippers in the body of the cheese, the impaired appearance of all cheese attacked by mites and skippers, the annoyance to manufacturers and dealers, and the expense connected with the treatment of cheese for the control of these pests. The presence of cheese skippers causes an additional loss to the industry through the sale of cheese containing the "cheese maggot," which tends to disgust the purchaser and lessen the consumption of cheese.

Occurrence.—The cheese mite is likely to become established in dairy sections where cheese is manufactured in several plants. It appears on aged cheese kept in curing rooms that are not well refrigerated. Sammis reports that the cheese mite seems to appear in Wisconsin whenever cheese is kept several months in an ordinary curing room. A large cheese dealer in New York states that nearly every year some difficulty is experienced with cheese mites and skippers. In California both mites and skippers have been observed in the same curing room. The mites attack the surface of the cheese and sometimes cause it to dry and crack, thus opening the cheese for the entrance of the skipper.

In the large cheese markets, both American Cheddar and Swiss cheese have been attacked. The Swiss cheese, on account of its larger size, is more subject to cracking on the surface and the consequent invasion of the cheese skipper. Soft varieties of cheese, such as Brick and Limburger, are especially subject to attack from cheese pests during the higher temperatures of the summer months, since the surface of these types is unparaffined and hence offers less resistance to their entrance.

Cheese favorable to parasitic growth.—Cheese pests require food, moisture, and warmth for their development. Since cheese is a concentrated food, sluggish parasites, such as cheese mites, can exist upon it without difficulty. The moisture content of cheese is also favorable to parasitic growth; that of hard cheese, such as Cheddar, averaging about 38 per cent, and of the soft varieties, such as Limburger, varying from 38 to 44 per cent. The temperature and humidity of the cheese-curing room may and frequently do favor the development of pests; but since these factors are subject to considerable adjustment, they may become very effective agents against both skippers and mites.

Both preventive and repressive measures are, however, dependant to a certain extent upon a knowledge of the life history and habits of the different pests, hence these points will be discussed before taking up the various phases of control work.

CHEESE SKIPPERS AND MITES

In almost every part of the world cheese skippers* and mites,† and at rare intervals a certain beetle,‡ are found feeding on cheese. References to the cheese mite date back hundreds of years, the species found in Europe being either identical with or closely related to those common in America and Australia. These pests are not confined to cheese as a food, the cheese skipper having achieved much of its notoriety as a feeder on the fatty portions of ham and bacon,⁷ while the mites freely attack a great variety of other foods.³

CHEESE SKIPPERS

The skipper or maggot found in overripe and often in moldy cheese hatches from an egg deposited by a fly (see fig. 1) and then burrows into the cheese, where it remains until full grown, when it comes to the surface and pupates. Cheese which has been severely attacked shows slightly sunken areas which, if cut into, will be found soft and waxy. When broken, such cheese has a stringy appearance, the grain being entirely lost. This condition may extend throughout the interior. To prevent and control loss of this nature, a knowledge of the different stages of the life history of the fly is essential. The length of time spent in the various life-history stages varies with the temperature, becoming very irregular in a temperature kept between 50° and 60° F.

LIFE HISTORY OF THE CHEESE FLY

Egg.—White, very slightly curved and narrow, somewhat tapering at each end. Length, one-thirtieth of an inch (0.7–0.9 mm.). Usually deposited singly over the surface of the cheese, particularly in cracks or broken surfaces. Time required for hatching, thirty to forty-eight hours at a temperature of 65° F., or one and one fourth to four days at 50° to 70° F.; at 50° F. and below, eggs have been held for weeks, but they hatched within a few hours when placed in a warm room.

* *Piophilina casei* Linn., Family Ephydridae.

† *Tyroglyphus siro* Gerv., *T. lintneri* Osb., *T. farinae* De Geer, *T. longior* Gerv., *T. terminalis* Banks, *Carpoglyphus anonymous* Haller. Family Tyroglyphidae. Experimental work reported herein has been upon the first two species.

‡ *Necrobia rufipes* De Geer, Family Cleridae. (Commonly known as the ham beetle.)

Larva (skipper).—The newly hatched maggot is transparent and so small as to be barely visible. When mature, it is yellowish white or light gray, about five-eighths of an inch (8 to 10 mm.) long. The head end of the larva is sharply pointed while the posterior end is blunt. At a temperature of 65° to 95° F., the length of the larval stage is from eight to fifteen days. At the normal temperature (50° to 65° F.) of most curing rooms, the larval period will extend much beyond this time and may possibly continue for months at the lower temperature.

The peculiar habit of the larva in curving the ends of the body together and then suddenly springing to a distance of from three to six inches has given it the name of “skipper.”



Fig. 1.—Illustrating the life history of the cheese fly; left to right, egg, larva (skipper), pupa, adult fly. ($\times 4$.)

Pupa.—The larva when mature seeks a secluded place and there changes into a pupa, a hard-shelled, brown case, about one-fifth of an inch (4 to 6 mm.) long. These pupae will be found scattered about under the cheesecloth covering or in dark places on the shelves. Length of pupal stage, seven to twelve days at 65° to 95° F., twelve to fourteen days at 55° to 60° F.; at 50° F. and below, pupae were held for five weeks without any flies appearing, but within ten hours after removal to a temperature of 80° F., 90 per cent of the flies had emerged from the pupae. Pupae held at 80° to 90° F. showed a 10 per cent emergence on the tenth day, an additional 40 per cent on the eleventh, and the remainder on the twelfth day.

Adult.—A dark, bronze fly with wings overlapping almost to the tip when at rest, about one-third the size of the common house fly (see fig. 2). Average length of life in confinement is seven to twenty days. Copulation occurs within two or three days after emergence from the

pupa at a temperature of 65° to 95° F. Oviposition begins two to four days later, making a total of from four to seven days after emerging from the pupa before the eggs are deposited.

Habits.—The cheese fly frequents storage and curing rooms and other situations where suitable breeding places may be found. They seem to prefer darkness rather than light, although they may go to a window in an effort to escape from uncongenial surroundings. Eggs have been deposited upon, and the skipper reared from, bacon, ham, slightly putrid beef,⁶ and oleomargarine, as well as cheese. The food usually preferred, however, is cheese. Cheese skippers have been found in butter packing rooms, but apparently they were feeding on other substances besides the butter fat, since larvae confined on butter alone



Fig. 2.—Showing comparative size and general appearance of the house-fly (left) and the cheese fly (right). The latter lays the eggs from which the skipper hatches. ($\times 4$.)

did not come to maturity. The presence of the skippers, in such a situation, however, emphasizes the need of sanitation throughout the factory. It also shows the danger in the escape of the cheese flies from infested rooms in the factory.

Fresh cheese, even when unparaffined, seems to be without attraction to the fly. In one infested factory, no eggs were found on cheese less than three weeks old, although flies were abundant in the curing room at the time. Cheese one month old was occasionally attacked, but in most instances that three months old or more was preferred. On paraffined cheese, eggs were found only where the coating was broken and then only on the exposed or immediately adjoining surface.

The larval habit of coming to the surface to pupate is of significance in fumigation work, as will be shown later, because the pupa has been found more or less susceptible to fumigation with hydrocyanic acid gas, while the skipper is practically safe when buried in the cheese.

CHEESE MITES

A brown powder scattered over the surface or in small depressions of the cheese is an indication of the presence of mites. In prolonged attacks, this powder may accumulate to the depth of one-half inch or more and fill cavities extending throughout the cheese. This powder consists of the dead bodies of mites, molted skins, excreta, tiny particles of uneaten cheese, and living mites. The mites are pale, soft-bodied animals just visible as small white specks. The body is usually twice as long as broad, with several conspicuous, long spines (fig. 4). In the adult and nymphal stages the mite is eight-legged, but in the youngest stage it has but six legs.

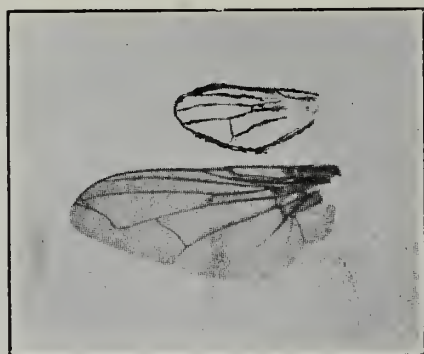


Fig. 3. Cheese-fly wing, upper figure. House-fly wing, lower figure. ($\times 4$.)

Life history.—Data concerning the different stages and development of a typical cheese mite have been gathered by Nellie B. Eales,² from whose description the following extract is made:

The life history, which is similar in all the species, consists of four stages, the egg, larva, nymph and adult male or female. From egg to adult stage occupies about four or five weeks. In working out the life history the method suggested by Michael was used.⁵ The eggs were white, oval bodies, so small as to be only just visible to the naked eye. They hatch in about ten to twelve days after being laid. On hatching the young mite is known as a larva. It is colorless and of glassy appearance, and has three pairs of legs only. The larva feeds actively for about a week, then becomes quiescent and casts its skin, emerging as the first nymph. The first nymph has four pairs of legs and is somewhat larger than the larva. It moults again and becomes the second nymph, larger and more highly chitinated than the first nymph. After its third moult, the nymph emerges as an adult male or female, the sexual organs not being functional until the final stage is reached.

In *Tyroglyphus longior*, however, there is an additional stage after the first nymph stage, which is specially adapted for distributing the species. This is known as the Hypopus stage and occurs under favorable conditions, when the mites are allowed to breed unchecked. The hypopus is like a minute tortoise. It is extremely small, pinkish in color, and has a hard, shelly back of chitin.

The legs are short, the mouth parts rudimentary, and there is no evidence that it feeds. On its ventral side it has a sucker plate by means of which it attaches itself to other mites, flies, and moths which alight on the cheese, or even to the skin and clothes of human beings. It is thus carried about until it finds a suitable place, when it drops off, moults to become a second stage nymph, and commences feeding.

Michael⁵ states: "hypopi development is most free under normal conditions, . . . it apparently being a natural stage in the development, although all individuals did not pass through this state."

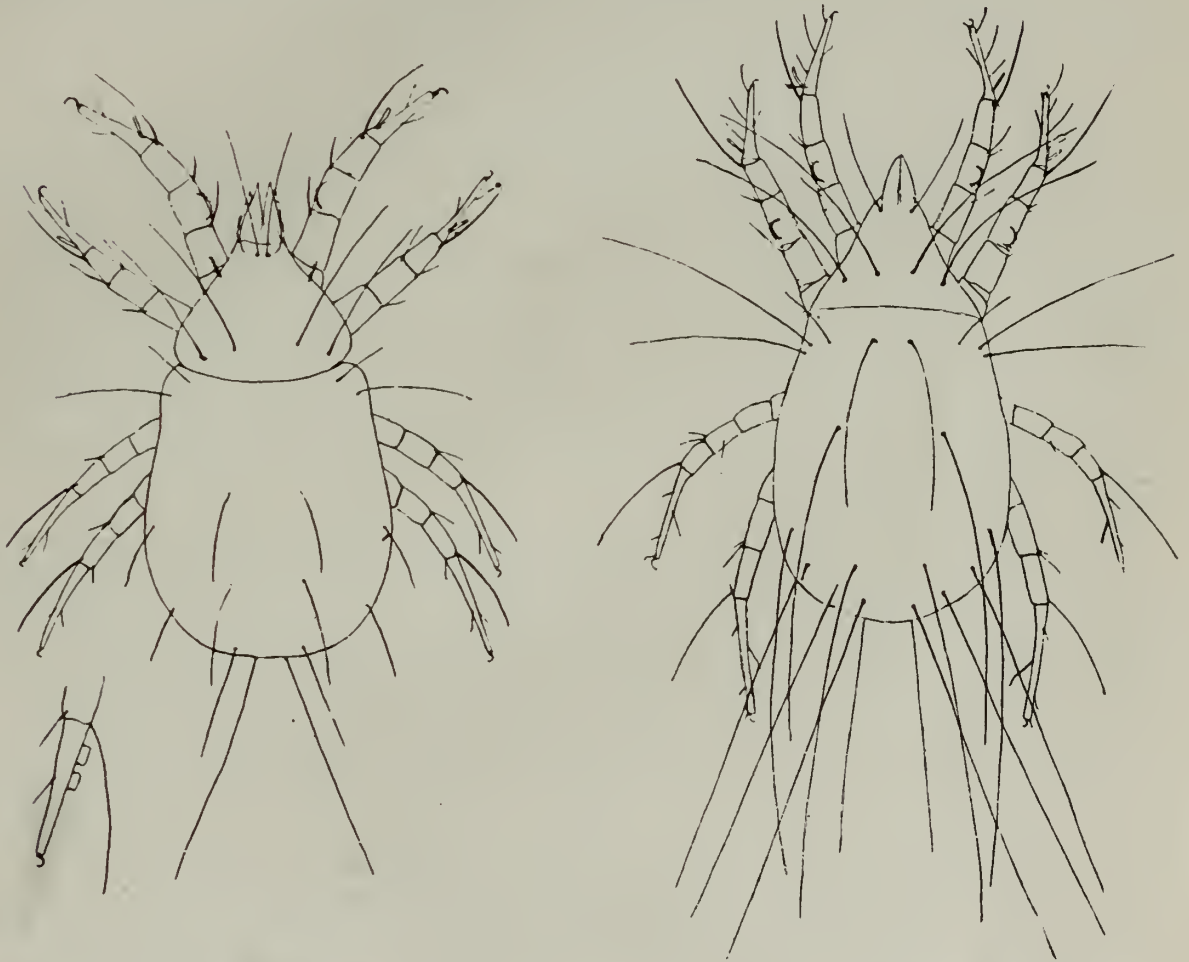


Fig. 4.—Enlarged drawings of the cheese mites *Tyroglyphus farinae* (left) and *T. lintneri* (right) (after Banks).

Feeding habits.—Mites attack cheese in various degrees of ripeness, but prefer the older stocks, providing these have not dried out. Like the cheese skipper, they are usually found at breaks in the coating of paraffin, in sheltered places, such as the cloth cover, or underneath the cheese. Mites obtain water only as it is present in their food; hence, if cheese becomes very dry, they cannot subsist upon it. Feeding is effected by means of pincher-like mandibles with which particles of food may be broken off and chewed. The mites which attack cheese vary in their feeding habits, and may feed on starchy materials, such

as grain and its by-products, sugar, and dried fruits. They are common visitors in grocery stores and wherever foods are stored for any length of time.

Distribution.—Mites may crawl from cheese to cheese, especially if the room is dark. Since such movement, however, is necessarily limited, dispersal depends principally on indirect methods. They may attach themselves, in the hypopus state, to moving objects or may be carried on the clothing of those working in the cheese rooms, or on equipment, and thus unwittingly be distributed. Mites in the younger stages may also be carried by sudden drafts of air.

PREVENTION AND CONTROL

The cheese skipper and the cheese mite, although differing in their life histories, thrive and develop in a similar environment. Dirty storage rooms, greasy shelves, old but moist cheese with broken paraffin coating in close proximity to the curing stocks, slightly humid atmosphere, and a temperature of 55° to 90° F. all favor the development of these pests, once they become established. If these conditions are guarded against, the more drastic measures of fumigation should seldom if ever be required.

Temperature and humidity.—Both skippers and mites are checked in their development by temperatures of 30° to 36° F. Prolonged exposure at this degree of cold may kill the cheese fly in any stage, unless it be the egg,⁷ but mites are more resistant to low temperature. According to experiments on one species, five months exposure to temperatures of 10°, 25°, 30°, and 36° F. killed only 60 to 80 per cent. Heat is much more dangerous to the mite than cold. Eales^{2b} reports that a temperature of 95° F. in a dry atmosphere was fatal to the mites but the same degree of heat in a humid atmosphere was harmless, and suggests that dipping cheese in hot water is not a good practice. Whitemarsh¹¹ found that the mites infesting cereals were killed when exposed to a temperature of 135° F.

Cold storage of cheese.—Slow curing of cheese at temperatures of 30° to 36° F. prevents loss through either skippers or mites. Even up to 50° F. injury from these pests is greatly restricted, but above this temperature activity and reproduction increase rapidly. A commendable practice, frequently followed in large cheese-producing regions, is to place the cheese in curing rooms at a temperature of 50° to 60° F. for one or two weeks only, followed by storage at 30° F.

Cheese is held in the curing room from one to four months, depending upon the market demand, if cold storage is not available, or if the cheese is marketed direct to the retailer. Under such conditions, the

danger of infestation is greatly increased, particularly in the summer. Certain markets will consume cheese held for a shorter period, and it may be considered good factory management where cheese pests are troublesome to market the cheese when one or two weeks old or to place it in cold storage until ready for consumption.

Paraffining.—Fresh cheese is apparently unattractive to the cheese fly and the mite, hence there is little danger of attack during the first few days of the curing period, but as ripening progresses the danger increases. As a protection against infestation, and for other reasons, it is customary to dip the cheese, when four to six days old, in paraffin heated to at least 220° F. This treatment covers the cheese with a thin coating of wax, which prevents shrinkage in weight through loss of moisture; preserves the palatability of the cheese, and aids materially in protecting it from pests. However, the cheese must be turned on the shelves during the curing period, the paraffin coating is frequently broken and its protective value thereby reduced. If cheese is held unnecessarily long in the bath, the butter fat will melt at the surface of the cheese and mix with the melted paraffin in gradually increasing quantities. Such a mixture weakens the coating, thus greatly lessening its protective value, and may even serve as food for the pests. Experiments with half-grown skippers confined with perfectly paraffined cheese resulted in their death, while larvae of the same age, confined with unparaffined cheese came to maturity. Paraffining should be considered as a protective measure against infestation rather than as a cure, and for this reason every effort should be made to keep the coating intact, so that neither skippers nor mites will find a point of entrance.

Screening.—It is desirable to screen cheese-curing rooms, and even the entire factory, particularly when located near other factories or cheese handling rooms, in order to prevent the entrance of the cheese fly. For such protection, wire screen cloth, 24 meshes to the inch, should be used. Common window screening having only 14 to 16 meshes to the inch will not exclude the fly unless cheese cloth is tacked over its surface.

Sanitation.—Thorough cleanliness in the cheese factory, and especially in the curing room, is the best safeguard against both mites and skippers. Accumulated grease on the shelves should be removed and no old cheese or scraps should be allowed to collect in or near the building. Any such material should be disposed of promptly by burning or utilized as a food for stock. If not removed it may serve as a breeding place for the cheese fly and mite, which upon maturity may find their way into the curing room. Avoid bringing into the factory

any cheese from public warehouses or other factories; or using old cheese containers, unless it is known positively that there is no danger of introducing pests by their use. Cheese presses and all apparatus where particles of cheese or other food might accumulate should be frequently and thoroughly sterilized with boiling water or steam.

Sales rooms or warm storage rooms.—The public sales room may frequently receive and store infested cheese. Here sanitation is likewise necessary to prevent infestation of clean stocks. Precautions should be taken against storing infested stocks in the same room with uninfested cheese. The cheese fly moves about readily and is quickly attracted to suitable food. The mite is more restricted in its movements, but on account of its small size it is easily overlooked and may remain inactive in the dormant condition for weeks and then suddenly begin an attack.

FUMIGATION

Exposing the cheese-curing room or factory to a poisonous gas is the most efficient method known for controlling both skippers and mites. For such work, the gas from sodium cyanid (hydrocyanic acid gas), carbon disulfid, or even burning sulfur may be used, their efficiency being in the order named. All three of these materials have been suggested by writers as possible fumigants, although with doubt as to their value.⁸ Hydrocyanic acid gas has proved the most effective, particularly against the pupal stage of the fly, in the work reported herein. It is, however, more dangerous to the operator than carbon disulfid, although the latter is very explosive. Both materials should be used with great caution. The use of burning sulfur is safest, but since it is less effective against the skipper, it cannot be generally recommended for this purpose, unless it be for the adult fly alone. Whatever material is used, prompt, thorough work is essential; otherwise the infestation may spread to such an extent as to make it difficult to exterminate the pests.

Preparing for fumigation.—The room to be fumigated should have a tightly constructed floor of matched lumber or a concrete floor. All cracks, ventilator openings, knot holes, and loosely fitting window sashes should be closed with some wet substance or should have paper pasted over them. Wet strips of newspaper will usually stay in position for a sufficient length of time. The use of a thin flour paste with a heavy sized paper will answer all purposes, and it is much easier to remove the paper so fastened than that attached with glue or gummed strips. The fumigation must be done thoroughly, for unless a large amount of gas can be held in the room for a number of hours, the operation will probably be a failure.

Curing rooms, used at normal temperature (50° to 60° F.) should be built so that successful fumigation is a possibility without the necessity of temporarily tightening the room. Such construction need not necessarily differ very much from that in common use. Infestation of curing or storage rooms, especially by the cheese mite, is not unusual,

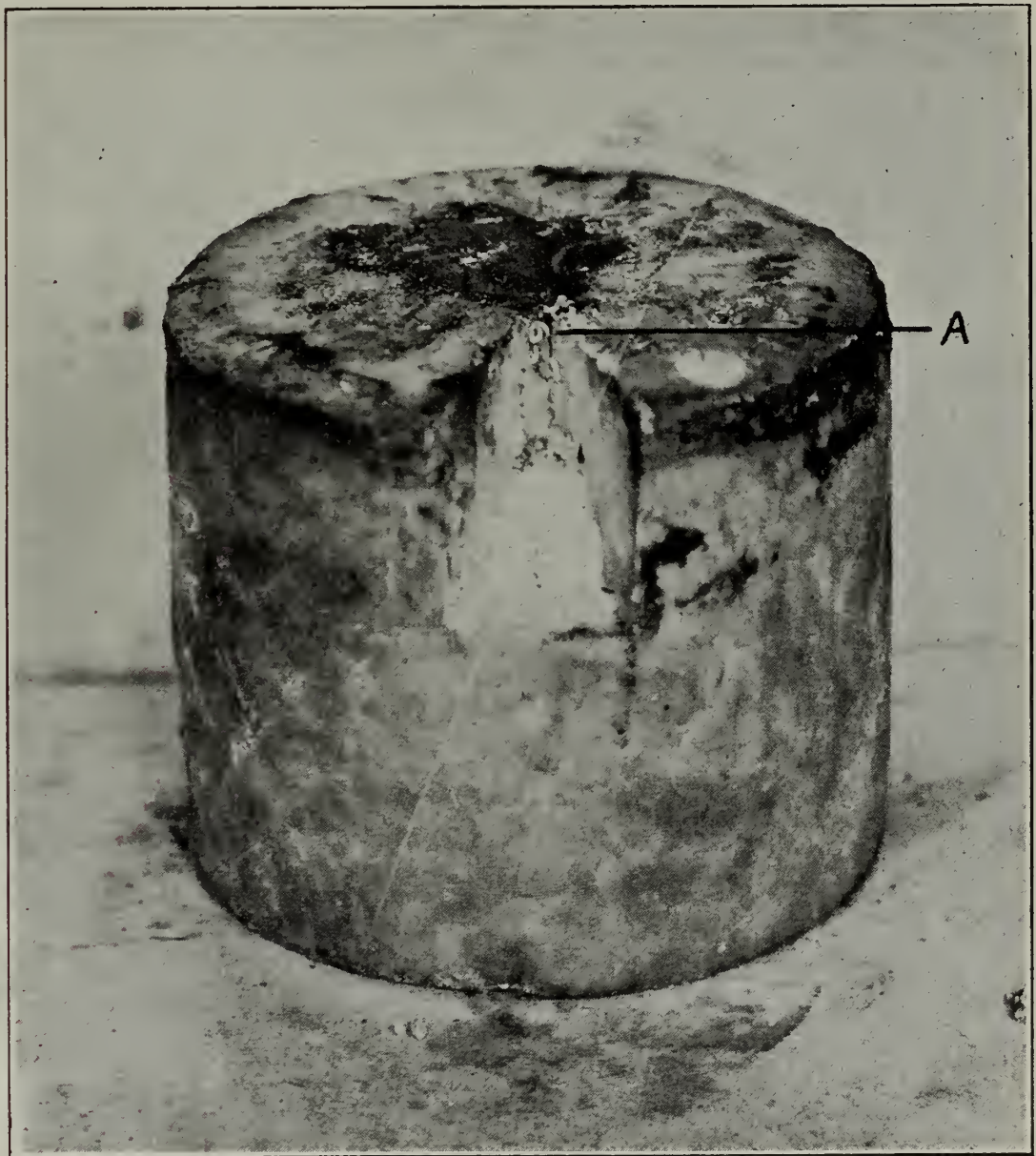


Fig. 5.—Junior cheese with section removed, showing larva (skipper) at the point of entrance.

and eradication is much easier in properly constructed rooms than where cracks or openings occur. The type of construction should be uniform throughout, with walls and ceilings made of concrete, cement plaster, or a double wall of matched lumber interlined with paper, and with a concrete floor. Concrete or plastered walls are porous and should be coated on the inside with liquid asphaltum, shellac, or silicate of soda, first painting once or twice with a 10 per cent solution

of sulfuric acid to prevent the liquid coating from peeling off after drying. The door should be of the refrigerator type, interlined with building paper and closing with clamps. The interlining for wooden walls should be a heavy glazed roofing or building paper, well lapped and glued at the joints. Doors and windows should be tight fitting and few in number. For convenience in airing the room, after fumigating, one window should be made to open from the outside. If carbon disulfid is to be used, electric switches should be placed on the outside of the room on account of the danger of explosion. Ventilators provided for regulating the humidity should be closed tightly, by covering with paper, while the fumigation is in progress. Shelving should be of surfaced lumber, free from cracks or knot holes, and resting on an angle iron frame, which facilitates the cleaning of both shelves and framework. Fumigation should always be done, if possible, at a temperature of 70° F. or above, although good results have been secured at 60° F. Insects are more active at high temperatures and consequently take in larger amounts of gas; for this reason rooms held at 45° to 60° F. should be raised to a temperature of 65° to 70° F. for a few hours just prior to fumigation.

General directions for fumigation.—Compute the capacity of the room in cubic feet and estimate the dosage according to the directions for the chemical to be used. During the day prepare for fumigation by making the room as tight as possible. Remove all materials, such as milk, butter, and water, that might absorb dangerous quantities of gas or become tainted. Otherwise disturb the room as little as possible, since the less it is disturbed the better the chance will be of eradicating the pests. If carbon disulfid or sulfur is used, the additional precaution should be taken of removing or coating with vaseline all nickel and plumbing or other highly polished metal surfaces. When the preparations are complete, remove from the room anything that might be wanted during the next twenty-four hours, *warn people in adjoining or overhead rooms of the possible danger*, and then set off the charge. This can usually be done most conveniently late in the afternoon, thus giving an all-night exposure or preferably a twenty-four hour exposure, if possible. It has been found by careful trials, the details of which will be given later, that it is apparently *unnecessary to remove paraffined cheese from the room* during fumigation. This saves much work in handling the stock and prevents the possibility of infesting other rooms where the cheese may be temporarily stored. All cheese remaining on the shelves should be slightly elevated on one side to allow free circulation of gas on the underside. Since fumigation has not

proved successful against the skipper buried in the cheese, or possibly against the egg, it becomes necessary to *repeat the treatment* after twelve to eighteen days in warm rooms, the shorter period being used only at maximum temperatures above 80° F., while, as the temperature drops, the time between fumigations lengthens to three weeks or more. These dates are based on the data secured in breeding the fly under

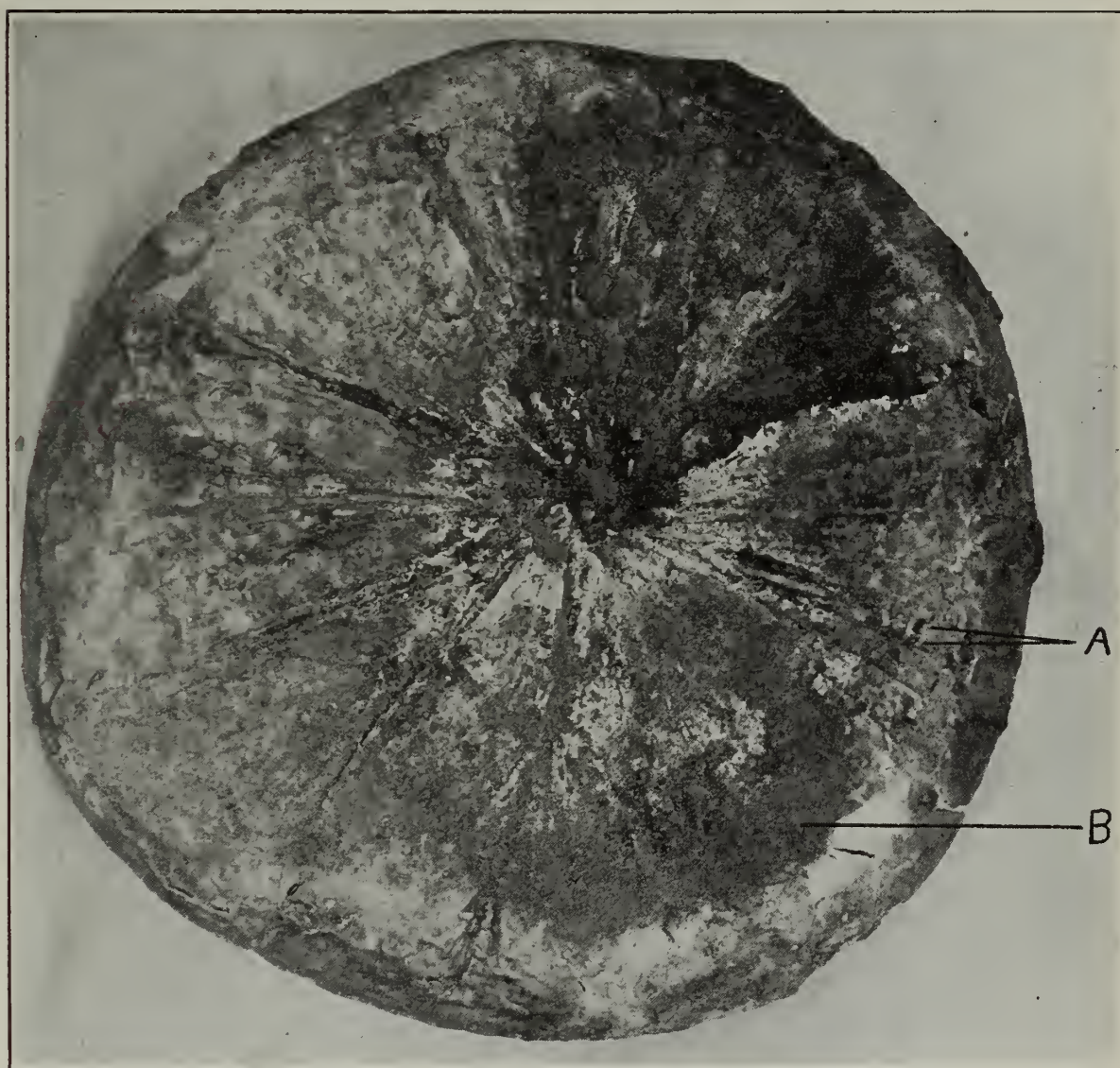


Fig. 6.—Surface of Jack cheese showing the pupae of cheese fly and the cheese mites appearing at the points indicated by arrows. *A*, pupa. *B*, mites.

confinement and naturally are subject to variations. At 50° F. or below, development is so irregular that no definite time for repeating the treatment can be given, the first appearance of flies in numbers being the criterion for the next fumigation.

Skippers buried in the cheese during the first fumigation would probably escape alive, but may have become susceptible at the second fumigation, either as pupae or newly emerged flies, and before they

have deposited eggs for a second generation of skippers. Two careful fumigations of the right dosage and correctly timed, followed by thorough cleaning should destroy all stages of the pest as they become susceptible. Building construction is so variable, however, that the correct dosage is difficult to determine. An error in the dosage, or carelessness in leaving a window or a ventilator open, may render one treatment valueless. In such cases a third fumigation is necessary. A close watch should be kept for flies several weeks after the final treatment; if an occasional fly is found it may be killed with a "fly swatter" before sufficiently mature to oviposit. If flies or mites appear in numbers after the second fumigation, it may be due to one or more of four reasons: the fumigation dosage was too weak; sanitation was neglected; flies entered from adjoining rooms or buildings; or new infestations were introduced in the cheese or its containers. A study of the conditions present will probably show the failure to be due to one or more of these causes.

In all fumigation work, the difference between control work and eradication must be kept in mind. Control consists in reducing the number of the pests to a point where they will not cause a serious loss but where under favorable circumstances new outbreaks may occur. Eradication means the destruction of all stages of either skippers or mites. The latter is necessarily much more difficult to accomplish than mere control, and where the infestation has spread throughout the entire factory, it is practically impossible to secure complete eradication unless the whole building is fumigated at the same time. This will require special provision for handling the milk outside the factory during the time required for fumigating, as it would be very dangerous to expose milk or water to hydrocyanic acid gas. For such cases it is possible to increase the charge and reduce the time of exposure to eight or ten hours.

(I) **Hydrocyanic acid gas** has proved the most efficient fumigant of any material experimented with, but it is also one of the most poisonous chemicals known. Even a small particle of sodium or potassium cyanid may prove fatal if accidentally eaten. It should not be handled without gloves if there are cuts or abrasions on the hands. *The cyanid for fumigation purposes should never be left where it may be handled by those unacquainted with its deadly nature, for it resembles sugar and might be eaten accidentally. Do not leave it near food, milk, or water. Use it only as directed, without any changes in method or of the formula, unless by an experienced operator. Unused supplies should either be buried or dissolved, then greatly diluted and poured down the sewer.* The gas is very dangerous to

breathe, except in dilute quantities, and even the sulfuric acid used in generating the gas burns severely if it comes in contact with the skin. One cannot too greatly emphasize the need of extreme care in handling such dangerous chemicals. If possible, the work should be placed in

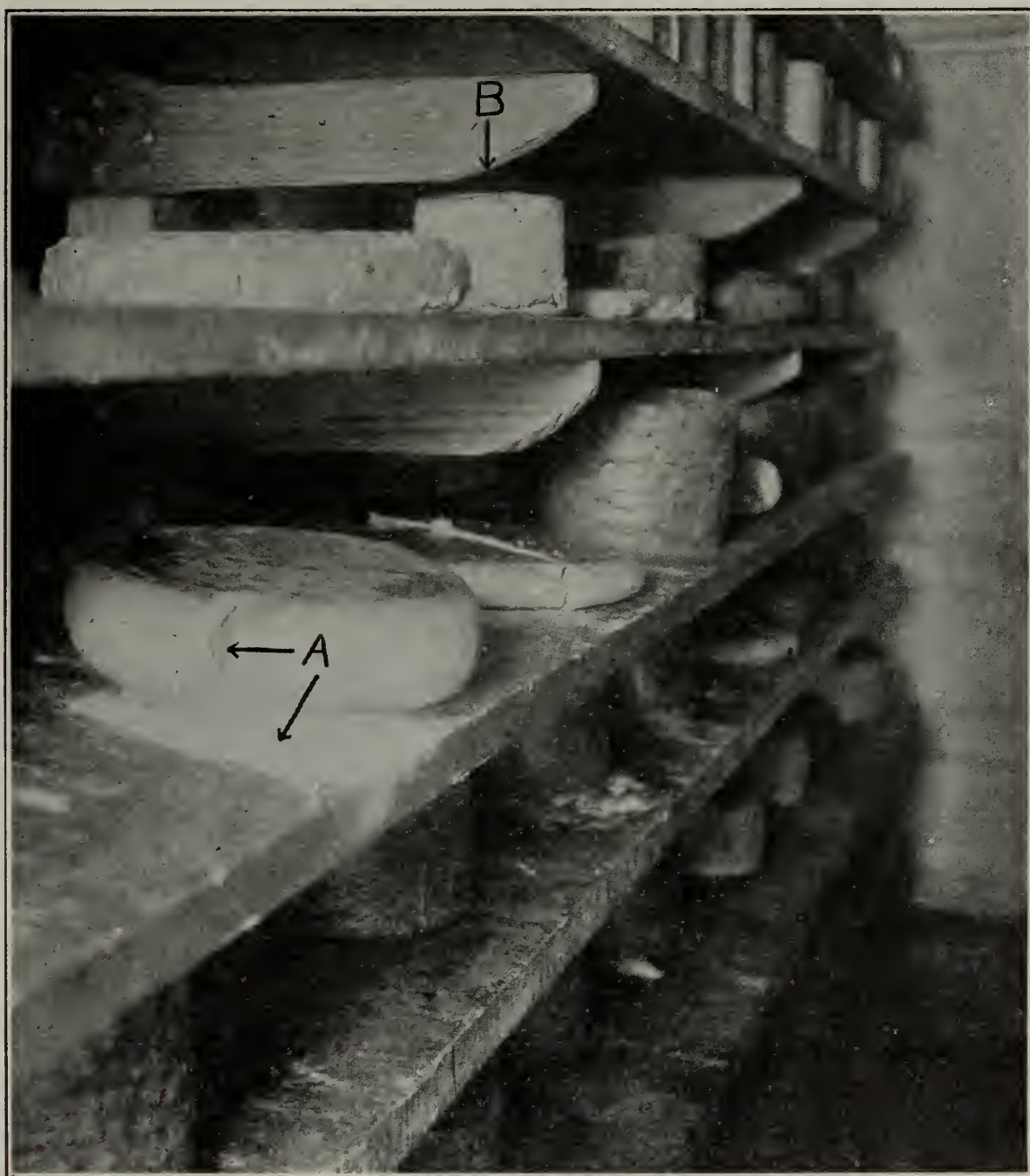


Fig. 7.—Corner of cheese curing room showing grossly infested cheese. *A*, Colony of mites living in a cracked cheese and on a greasy shelf. *B*, Old cheese, a possible breeding place for pests.

the hands of experienced operators. These warnings, however, need not deter anyone from the use of this valuable fumigant, provided directions are carefully followed. Cyanid has been widely used as a fumigant for orchards, nursery stocks, mills, warehouses, and homes

for twenty-five years, with almost no fatal accidents to human beings, the very few known authentic cases having been due to carelessness. This gas is not explosive, as is that from carbon disulfid, neither does it have the bleaching or corroding effect of the latter or of burning sulfur. These factors, coupled with its great efficiency, have increased its popularity as a house fumigant, so that it has largely displaced other materials, except for quantities of stored products where great penetration is desired.

Materials used in fumigation.—Potassium cyanid was until recently the most common form on the market. This has been displaced by sodium cyanid which, for fumigating purposes, is made in one-ounce lumps to avoid the necessity of weighing. It should be 98 to 99 per cent pure and contain 50 to 51 per cent cyanogen. There are grades of cyanid on the market for artisans' and miners' use, which are much weaker (50–60 per cent pure instead of 98 per cent) and these should be used in proportionately greater amounts.

The gas is generated by adding the cyanid to a solution of sulfuric acid. The commercial acid used in testing milk and cream is as satisfactory for this purpose as the refined grade. The water required in the generation of gas prevents the acid from charring the cyanid, generates heat by combining with the acid, and holds in solution the sodium sulfate which is formed.

The amount of sodium cyanid required for a tightly built room is $1\frac{1}{2}$ ounces per 100 cubic feet, the chemicals being used in the following proportions:

Sodium cyanid	$1\frac{1}{2}$ pounds
Sulfuric acid	$2\frac{1}{4}$ pints
Water	3 pints

A room, $10 \times 16 \times 10$ feet, contains 1600 cubic feet and would require $1\frac{1}{2}$ pounds of sodium cyanid, $2\frac{1}{4}$ pints (66 ounces by weight) of sulfuric acid, and 3 pints of water. The proportions for the chemicals given should not vary, but the amount used per hundred cubic feet must be determined according to the tightness of the room. The above amount of cyanid may be reduced one-third in a room built especially for fumigating purposes, with a corresponding change in the amounts of acid and water. Twice the above dosage, or even more, should be used for buildings of only approximate tightness. Generally speaking, it is safer to use an excess of cyanid and acid than to fall below the standard given, for a weak concentration of gas will accomplish nothing.

Process of fumigation.—Earthenware jars or wooden buckets make good generators, tall narrow ones being preferable to low, broad ones. If a wide-bottom generator is used, the water and acid solution may be so shallow that the cyanid will not be entirely dissolved. To avoid this danger it may be necessary to use an excess of the dilute acid to insure covering the lumps of cyanid, but the better plan is to use the normal amounts of ingredients in a deep, narrow container. Large rooms should have two or more generators, none of which should contain

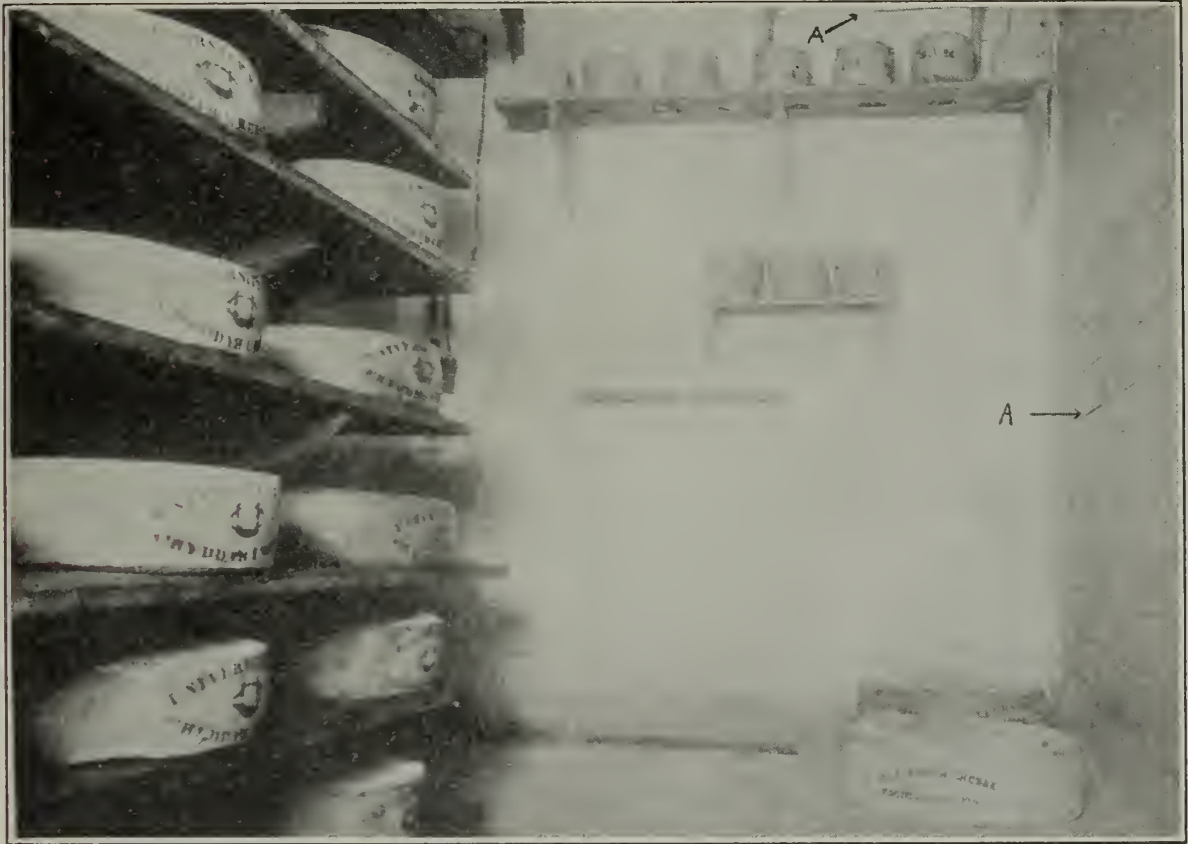


Fig. 8.—Curing room constructed of tongue and groove lumber, showing crack (a) too large to permit effective fumigation.

more than $2\frac{1}{2}$ pounds of cyanid, and for this amount a five or six-gallon generator should be used. Since hydrocyanic acid gas is lighter than air, the generator is placed at the lowest level, the floor and everything within three feet of the generator being protected by a mat of newspapers to avoid any possible spatter of acid.

The water is first measured and poured into the generator, next is added the required volume of acid, poured in slowly to avoid splashing. *Do not reverse the order of mixing, as severe spattering may result.* The water and acid should be combined immediately before generating the gas, as an acid solution of about 180° F. will free more gas than a cold solution. The cyanid, which should be placed in a paper bag to delay the generation of the gas, is now dropped into the acid solution, and the operator must then leave the room as quickly

as possible, closing and locking the door behind him. As a further precaution, a notice should be attached to the outside of each door, stating that the room is being fumigated and should not be entered. Occupants of adjoining rooms or those overhead should be notified of the operation, as sufficient gas might escape into these rooms to cause serious danger to the occupants. The room should be closed for at least twelve and preferably for twenty-four hours. A door or window should then be opened from the outside and the room ventilated before anyone is allowed to enter.

(II) **Carbon disulfid** is an oily liquid giving rise to a heavy vapor, which when confined at a sufficient concentration, is poisonous to insects and higher animals. This material is not so dangerous to handle as hydrocyanic acid gas, but care must nevertheless be taken by the operator while working with it. Although the gas has a strong odor, it quickly deadens the sense of smell, so that the operator may not realize that he is still exposed to the fumes; continued exposure may be followed by nausea and dizziness, ending in suffocation. On account of this danger, it is always best for two men to work together in fumigating a large building. Since the gas is heavier than the air and will always settle to the lowest levels, it should be exposed above the highest layer of the material to be fumigated.

Process of fumigation.—The amount of carbon disulfid to be used varies from *ten to thirty pounds* per 1000 cubic feet, according to the tightness* of the room or bin, the larger amount being for a room of only approximate tightness.

The carbon disulfid is poured into broad-bottomed, shallow pans which may be placed directly on top of the material to be treated or on the highest points in the room which are easily accessible. The pans should not be filled more than one-half inch deep, as it is necessary to expose to the air as large a surface of the chemical as possible and every effort should be made to hasten its vaporization. The use of a spray pump is very convenient for distributing the liquid over the material to be fumigated, or against the exposed walls and ceilings when large rooms are being treated. Another method is to hang waste, saturated in the carbon disulfid at different places in the upper part of the room. The room is closed from twelve to twenty-four hours and then well ventilated before anyone is allowed to enter. The same precautions against accident should be taken as with cyanid.

(III) **Sulfur** has proved effective against the cheese mite, and in some instances would probably kill the adult fly, but it cannot

* A pint of the liquid will weigh about 1.3 pounds.

be depended upon to kill the skipper or the pupal stages of the cheese fly. Sulfur fumes will corrode nickel and in the presence of moisture will bleach colored fabrics. The usual precautions of tightening rooms and working at a temperature of 60° F. or above should be taken. When sulfur candles are used, they may be placed on a float in a tub of water, lighted, and the room closed. Coarse grades of sulfur may be burned in metal containers. These should be at least twelve inches distant from any inflammable material. Time of exposure is from twelve to twenty-four hours.



Fig. 9.—The cheese curing room shown in fig. 8, with walls covered with paper and joints pasted to increase the effectiveness of fumigation.

FINAL CONTROL MEASURES

After fumigation it is advisable to remove all shelving used for cheese, scrape it thoroughly, and wash with strong cleaning solutions or lye water to remove the deposit of grease. Cheese suspected of being infested should be disposed of. That which is only slightly damaged may be trimmed and sold as cooking cheese. The trimmings and badly infested cheese should be promptly removed to a distance from the factory or store room and disposed of by burning or feeding to stock. Fumigated rooms should be inspected every day or two for at least one month and preferably longer for the presence of

the cheese fly in any stage, or mites. Adult flies may gain entrance to the curing room from other parts of the building, but by prompt action these may be killed before they have opportunity of ovipositing. If the control measures extend into the fall months, or if the rooms are held permanently at 65° F. or below, there will be a slow irregular development of the pests; hence it becomes necessary to remove all cheese that was exposed to infestation, before any skippers which may be present mature. The inspection of the uncooled curing rooms, for the presence of pests, should begin in April and be repeated two or three times a week during the late spring and early summer. Neglect at this time may necessitate the repetition of the entire fumigation program.

EXPERIMENTAL FUMIGATION DATA

The results secured in experimental work, leading up to the determination of effective dosages, are given in table 1. These data are given to emphasize the variation in results in different types of fumigators with varying lengths of exposures.

TABLE 1

FUMIGATING EXPERIMENTS* FOR CONTROL OF CHEESE SKIPPERS AND MITES†

Type of fumigator	Fumigant used	Amount per 1000 cu. ft.	Length of exposure	Remarks
Cheese room partly papered	Sodium cyanid	30 ounces	24 hours	Cheese fly, exposed skippers, ham beetles, and cheese mites all killed.
Fumigating box, tongue and groove lumber	Carbon disulfid	33 pounds	48 hours	60% of skippers on surface of cheese killed, 90% of those in cheese recovered.
Cheese storage room, tight walls	Sodium cyanid	20 ounces	48 hours	All cheese mites killed.
Five-gallon stone jar	Carbon disulfid	5 pounds	7.5 hours	All skippers alive.
Wooden fumigating box	Carbon disulfid	10 pounds	24 hours	All skippers alive.
Stone jar	Carbon disulfid	10 pounds	24 hours	All skippers alive.
Stone jar	Carbon disulfid	20 pounds	24 hours	All exposed skippers dead. 3% of those buried in the cheese escaped.
Wooden fumigating box	Carbon disulfid	20 pounds	24 hours	All skippers alive.
Stone jar	Sulfur (burned)	10 pounds	26 hours	All mites dead. Skippers alive.

* Temperatures 70° to 80° F.

† Species experimented upon *Tyroglyphus siro* Gerv.

From the above data it would appear that the cheese fly larva (when exposed), the ham beetle, and the cheese mite may be killed with a dosage of from 20 to 30 ounces of sodium cyanid per 1000 cubic feet in rooms approximately tight. Skippers buried in the cheese cannot all be killed even with excessive dosages of carbon disulfid (which is even a more penetrating gas than that from sodium cyanid). Sulfur gave satisfactory results against the cheese mite in the one experiment performed, but was of no value against the skipper. There has been a lack of opportunity to determine exact dosages for sulfur in different types of fumigators, but the range would probably be from six to ten pounds per 1000 cubic feet to control the cheese mite. This material seems impracticable as a control for the cheese fly except perhaps in the adult stage.

POSSIBILITY OF THE ABSORPTION OF FUMIGATING GASES BY CHEESE

Practical fumigation trials in cheese factories and storage rooms have shown the desirability of leaving the entire stock of cheese untouched while the room is being fumigated. This prevents the possibility of scattering the infestation and also obviates the labor of moving the stock in and out of the room. To determine whether sufficient amounts of the fumigating gases are absorbed to make it dangerous to eat the cheese treated, the following experiments were tried:

A test for the absorption of gas was made during the actual fumigation of a curing room, a dosage of approximately three ounces of sodium cyanid per thousand cubic feet being used. Time of exposure, twenty-four hours; temperature between 60° and 70° F. Twenty cheese fly pupae were placed in the room prior to fumigation to test the action of hydrocyanic acid gas on the fly in this stage. Five more pupae of the same age were kept as a check. Flies emerged from each of the latter a few days later, but none from the fumigated pupae. The adult cheese fly and cheese mites were both killed during this treatment. Four whole, paraffined cheeses (two "full-cream" and two "jack") and a slice of freshly cut cheese were left in the room during fumigation. These were tested for odor or flavor of gas fifteen hours after the opening of the room. Cuts were made from the surface and from the inner portion of each whole cheese and also from the cut cheese; every sample was tested by five members of the Dairy Industry Division of the University of California, all of whom are accustomed to competitive judging of commercial cheese. In all, twenty-five people tried these samples, and not one could distinguish.

by taste or smell, the samples of fumigated cheese from those which were untreated. Several ate freely of the fumigated cheese without noting any ill effects.

*Effect of fumigated cheese on mice.**—Two series of experiments were made: (1) The comparative absorption of hydrocyanic acid gas by three unparaffined “Cheddar” cheese, one of which was a “skim,” another a “one-half skim,” and the third a “full cream” cheese. (2) The comparative absorption of the fumigating gases by aged and fresh “one-half skim milk” and “full cream” cheese.

No. 1. Type of cheese used:

- 2 “Cheddar” “skim milk” cheese made Sept. 11, 1920.
- 1 “Cheddar” “one-half skim milk” cheese made Sept. 9, 1920.
- 3 “Cheddar” “full cream” cheese made Sept. 12, 1920.

Date of experiment, Sept. 20, 1920.

The experiments were conducted in special fumigating boxes, one being a paper-lined, double-walled box of 150 cubic feet capacity; the second of the same size but with concrete walls, painted on the inside with liquid asphalt.

Time of treatment, 24 hours. Dosage: Box 1, ten ounces of sodium cyanid (98 per cent pure) per 1000 cubic feet; Box 2, six pounds of carbon disulfid per 1000 cubic feet. Temperature of boxes during fumigation, 62°–64° F.

To make sure that a fatal dosage had been used, specimens of the cheese mite, an adult cheese fly, and three pupae (and in Box 1, a single specimen of the cheese beetle) were placed in each box during the fumigation period. All these were killed by the above dosage except the fly pupae. The failure in the case of the latter can probably be attributed to the low temperature at which the experiment was conducted. After the cheese had been fumigated it was removed and the following experiments conducted with white mice: Series (A) and (B) are alike except in the fumigating materials used, sodium cyanid being used in the former and carbon disulfid in the latter.

* No experiments were made to determine the fatal dosage of hydrocyanic acid gas to white mice, but a number of the common house mice (*Mus musculus*) were killed with the ordinary dosage while fumigating the storage room. In similar experiments made by the United States Public Health Service⁹ it was found that white mice are quite susceptible to this gas.

Series A. Hydrocyanic acid gas.

1. Two mice were placed in a screened enclosure with fumigated cheese, and forced to eat from the cut surface that had been exposed to the gas.

2. The same as experiment 1 except that the cheese was aerated two hours before the mice fed upon it.

3. Two mice were placed in a screened enclosure with cheese treated as in experiment 1, but surrounded with a screen to prevent their eating it, and were fed only on unfumigated cheese.

4. Two mice were placed under a bell jar with fumigated cheese, protected with a screen to prevent their eating it, to determine if enough gas was present to kill by inhalation.

5. Two mice were placed under a bell jar with exposed cheese, aerated for two hours and protected with a screen to prevent their eating it, to determine if danger from inhalation of gas had been passed.

Series B. Entire series repeated with carbon disulphid as the fumigant.

Observations.—The mice in experiments 1 and 2 of both series A and B suffered no ill effects from eating the freshly fumigated cheese; within thirty minutes after their forced feeding they were eating freely of the treated cheese upon which they continued to feed for almost two days. No abnormal conditions could be noted for *thirty-six* hours among any of the mice experimented upon, during which time they were observed frequently. One mouse in series A, experiment 1, died forty-two hours after the forced feeding. This could have no direct connection with hydrocyanic acid gas, for death from such a cause would have come very quickly. Autopsy findings indicated that death was caused by pneumonia.

No difference could be determined in the absorption of gas by the types of cheese used, from the action of mice to which it was fed. Neither could more than a mere trace of either carbon disulphid or hydrocyanic acid gas be detected by the operators.

No. 2. The second series of experiments was made to determine the comparative absorption of fumigating gases by aged and fresh cheese and also "Cheddar," "one-half skim" cheese, and "full cream" cheese. The fumigation was begun on September 22 and the tests on the mice were made the following day. The work was conducted in the same fumigating box, with the details of dosage, length of exposure,

and temperature similar to those of series 1, except that this experiment was with hydrocyanic acid gas alone. The same tests were used on the mice as in the first series.

Types of cheese used:

- 2 "Cheddar skim milk" cheese made June 29, 1921.
- 1 "Cheddar full cream" cheese made June 9, 1920.
- 1 "Cheddar full cream" cheese made April 17, 1920.
- 1 "Cheddar one-half skim milk" cheese made June 29, 1920.

Date of experiment, Sept. 22, 1920.

Observations.—Cheese, thirty minutes after removal from the fumigator, had a slightly perceptible odor which one person identified as hydrocyanic acid gas. At this time both persons making the test ate cheese the size of a walnut and smaller pieces with no ill effects whatever.

The mice in experiment 2 attempted to feed on freshly fumigated cheese within five minutes after being placed in the cage. Apparent distaste was shown at this time, but within fifteen minutes both mice were feeding freely from this same cheese.

No ill symptoms were noted among any of the mice experimented upon five hours after they had eaten the freshly fumigated cheese. A few of the mice escaped that night and, owing to unavoidable circumstances, mice died the following day both in the check and among those experimented on. No fatalities or abnormal conditions occurred which could be attributed to the action of the hydrocyanic acid gas.

Many samples of cheese fumigated at different times were examined by several persons, including cheesemakers and expert judges of dairy products, and in no instance did they detect any odor or flavor of the fumigating gases. However, two people, accustomed to working with hydrocyanic acid gas, detected it in fumigated cheese in another series of experiments. This odor was entirely lost after a short aeration. Three persons ate one-half ounce or more of the freshly fumigated cheese without ill effects.

SUMMARY

Cheese skippers and mites attack cheese in almost every part of the world. They are widely distributed in the United States and are frequently reported from the principal cheese-producing states.

The loss caused by these pests arises from: cheese actually eaten, damaged appearance of attacked stocks, prejudiced customers, annoyance to manufacturers and dealers, and the expense of control measures.

Old cheese with broken paraffin covering, greasy shelves, dirty factories, and warm curing rooms favor the development of skippers and mites.

Fresh cheese is seldom attacked by either pest, but infestation may begin during or at any time after the first month of the curing period.

Cold storage of cheese at 30° to 36° F. is the most practical method of preventing loss from either skippers or mites. If cold storage is unavailable the cheese should be marketed while fresh.

Paraffining cheese aids in protecting it from attack if the coating is unbroken.

Fumigation of infested rooms with hydrocyanic acid gas or carbon disulphid is the most efficient method known for controlling both skippers and mites.

Hydrocyanic acid and carbon disulphid are dangerous poisons and should be used only as directed, and if possible, only by experienced operators. Do not leave them where they may be handled by those unacquainted with their dangerous nature.

Fumigation should always be supplemented by a thorough cleaning of the infested rooms and the prompt disposal of all aged cheese.

It is apparently unnecessary to remove cheese from a room during fumigation; the risk of scattering the infestation while transporting the stock to another room and the expense of handling may thus be avoided.

Cheese of different types and ages showed no absorption of hydrocyanic acid gas or carbon disulphid. The odor which was apparent immediately after removal from the fumigating room disappeared after a short aeration. The cheese had no objectionable odor or flavor when eaten two hours later.

Sulfur burned in the fumigating room gave a partial control of the mites but was of little value against the skipper.

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